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GUIDELINE SERIES

CONTROL OF VOLATILE ORGANIC EMISSIONS FROM EXISTING STATIONARY SOURCES VOLUME IV: SURFACE COATING FOR INSULATION OF MAGNET WIRE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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16. ABSTRACT

This report provides guidance for development of regulations to limit emissions of volatile organic compounds from magnet wire coating operations. Coating operations and control technology are described. Reasonably Available Control Technology (RACT) is described for the industry.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Magnet Wire Wire Enameling Emission Limits	Air Pollution Control Stationary Sources Organic Vapors	

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CONTROL OF VOLATILE ORGANIC EMISSIONS FROM EXISTING STATIONARY SOURCES VOLUME IV. SURFACE COATING FOR INSULATION OF MAGNET WIRE

Emissions Standards and Engineering Division
Chemical and Petroleum Branch

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

December 1977

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PREFACE

This report is one of a continuing series designed to assist State and local jurisdictions in the development of air pollution control regulations for volatile organic compounds (VOC) which contribute to the formation of photochemical oxidants. This report deals with VOC emissions from wire coating ovens.

Below are provided emission limitations that represent the presumptive norm that can be achieved through the application of reasonably available control technology (RACT). Reasonable available control technology is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, but not necessarily identical source categories. It must be cautioned that the limits reported in this Preface are based on capabilities and problems which are general to the industry, but may not be applicable to every plant.

The most common control technique used for wire coating ovens is incineration. Essentially, all solvent emissions from the oven can be directed to an incinerator with a combustion efficiency of at least 90 percent. This efficiency is reasonable to attain. Thermal incinerators have an efficiency range from 90 to 99 percent. Catalytic oxidizers have an efficiency range of 90 to 95 percent if not fouled.

Low polluting coatings are beginning to be used in the wire coating industry. It is reasonable to exempt an oven from the incineration requirement if the coatings used contain less than the recommended limitation given below for low solvent coatings.

Affected Facility	Recommended Limitation for Low Solvent Coatings	
	kg solvent per liter of coating (minus water)	lbs solvent per gallon of coating (minus water)
Wire Coating Oven	0.20	1.7

This emission limit can be met with high-solids coatings having greater than 77 percent solids by volume. Powder coatings and hot melt coatings will both achieve this. This emission limit can also be met with a water-borne coating which contains 29 volume percent solids, 8 volume percent organic solvent, and 63 volume percent water. A water-borne emulsion with no organic solvent would, of course,meet the recommended limit.

Approximately the same amount of solvent will be emitted from a low solvent coating meeting the above limitation as from an equal volume of solids applied as a conventional coating with 90 percent incineration of solvent emissions from the conventional coating.

Many wire enameling ovens already have incinerators which reduce volatile organic compound (VOC) emissions. Because of the number of sources already controlled, national emissions from wire enameling is not so great as from some other sources. But a wire enameling plant with only a few uncontrolled ovens could easily exceed 91 Mg/year (100 tons/year) of VOC

emissions. Thus, a wire enameling plant can be a significant source in a local area.

SUMMARY

Wire enameling is the process of insulating electrical wire by applying varnish or enamel. Organic solvent is driven off in the wire drying oven. Incineration, either thermal or catalytic, is the most common way to control these solvent emissions. Control efficiencies of 90 to 95 percent are typical. Because of the high oven temperatures and high solvent concentrations in the exhaust, this is a favorable situation for heat recovery. The fuel value of the waste solvent may be used to supply much of the heating requirements of the oven.

CONVERSION FACTORS FOR METRIC UNITS

Metric Unit	Metric Name	Equivalent English Unit
Kg	kilogram (10^3 grams)	2.2046 lb
liter	liter	0.0353 ft^3
dscm	dry standard cubic meter	35.31 ft^3
scmm	standard cubic meter per min.	35.31 ft^3/min
Mg	megagram (10^6 grams)	2,204.6 lb
metric ton	metric ton (10^6 grams)	2,204.6 lb

In keeping with U.S. Environmental Protection Agency policy, metric units are used in this report. These units may be converted to common English units by using the above conversion factors.

Temperature in degrees Celsius (C°) can be converted to temperature in degrees Farenheit (°F) by the following formula:

$$t°_f = 1.8\ (t°_c) + 32$$

$t°_f$ = temperature in degrees Farenheit

$t°_c$ = temperature in degrees Celsius or degrees Centigrade

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1.0 SOURCES AND TYPES OF EMISSIONS

1.1 GENERAL DISCUSSION

Magnet wire coating is the process of applying a coating of electrically insulating varnish or enamel to aluminum or copper wire for use in electrical machinery. The wire is called magnet wire because, in such equipment as electrical motors, generators and transformers, this wire carries an electrical current which creates an electromagnetic field. The wire coating must meet rigid specifications of electrical, thermal and abrasion resistance.

Magnet wire is usually coated in large plants which both draw and insulate the wire. The wire is then sold to manufacturers of electrical equipment. There are approximately 30 enameling plants in the United States. These are located in several States including New York, Connecticut, Illinois, Virginia, Massachusetts, North Carolina, Georgia and Louisiana. The largest geographical concentration of wire coaters is Fort Wayne, Indiana. Several companies have wire enameling plants there.

1.2 PROCESSES AND AFFECTED FACILITY

1.2.1 Processes

Figure 1 shows a typical wire coating operation. The wire is unwound from spools and passed through an annealing furnace. Annealing softens the wire to make it more pliable for its trip over the pulley network and also acts as a cleaning chamber to burn off oil and dirt left from previous operations.

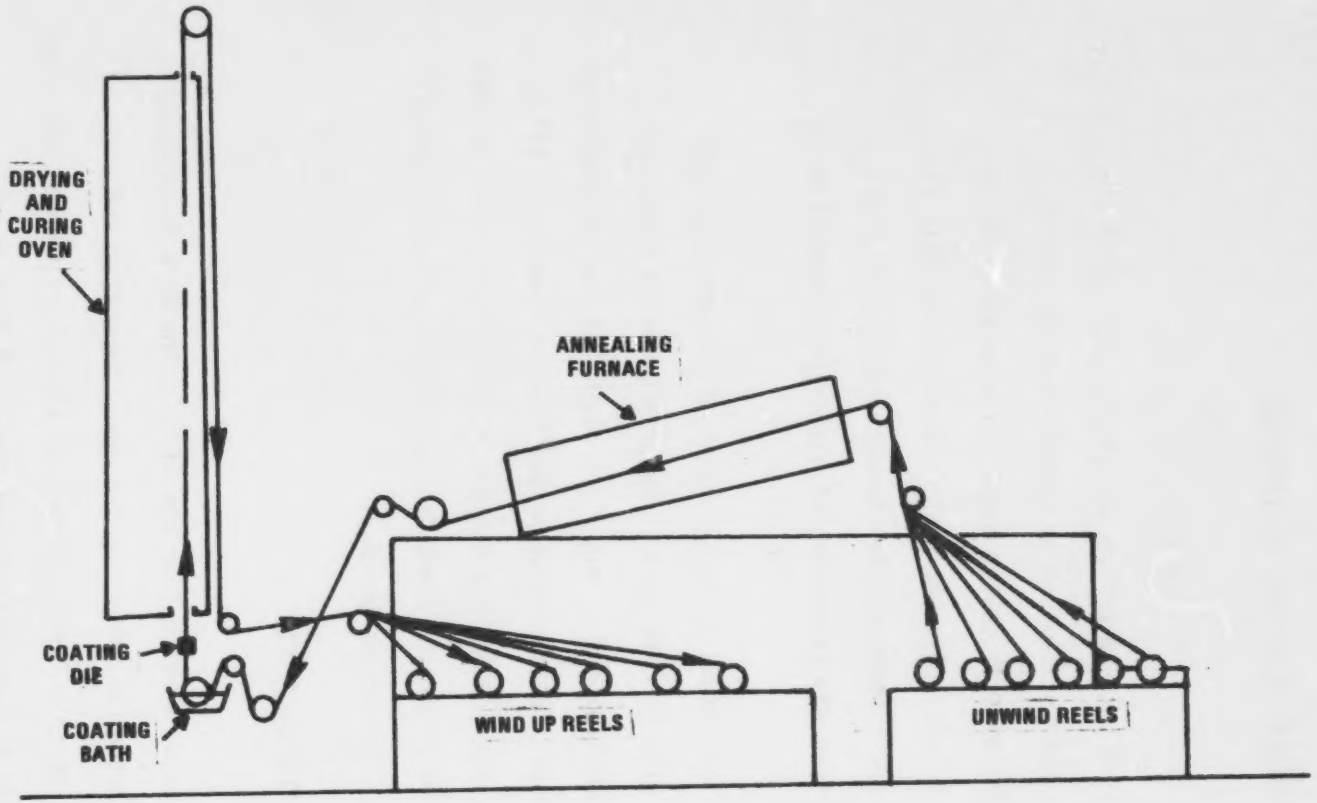

Figure 1. Typical wire coating line.

The wire is then ready for coating. There are several variations on the method of application. Typically, at the coating applicator the wire passes through a bath of coating and picks up a thick layer of coating. The wire then is drawn vertically through an orifice or coating die as shown in Figure 2. The die scrapes off excess coating and leaves a thin film of the desired thickness.

After the wire passes through the coating die, it is routed through the oven where the coating dries and cures. The exhaust from the oven is the most important solvent emission source in the wire coating plant.

Most coating ovens consist of two zones. Wire enters at the drying zone which is held at about 200°C. The second or curing zone and the temperature here is around 430°C.

At some plants there is a noticeable solvent odor near the coating applicator indicating incomplete capture. In others, solvent from the coating bath appears to be drawn into the oven by its indraft. At any rate, the solvent emissions from the applicator are low compared to the principal emission source, the drying oven.

The exhausts from typical ovens range from 11 dry standard cubic meters (dscm) per minute to 42 dscm per minute with the average being around 28. The solvent concentration in the exhaust will typically range from 10 to 25 percent of the LEL (lower explosive limit). This would be equivalent to about 12 kg solvent per hour emissions from the oven. Each oven usually operates three shifts per day for seven days a week. It is not unusual for a wire coating plant to have 50 coating ovens. An uncontrolled plant could easily emit more than 90 Mg (megagrams) per year of solvent which would make it a significant source of VOC emissions.

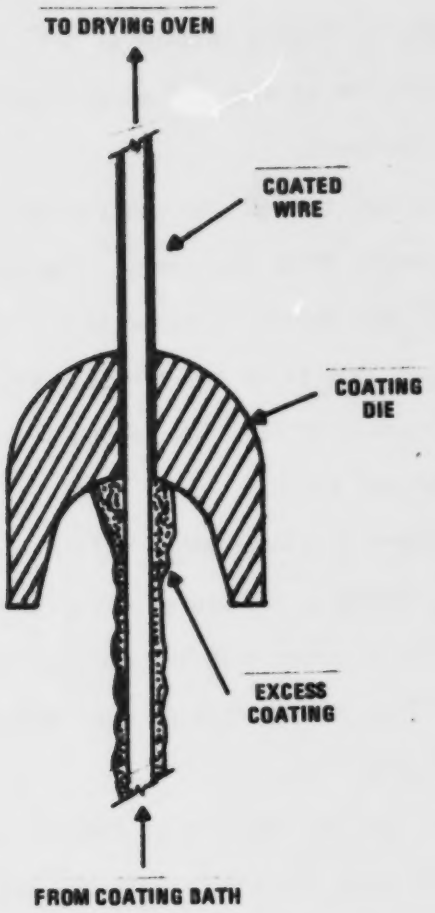

Figure 2. Wire coating die.

After a wire passes through the oven and the coating is cured, it again passes through the coating applicator and oven to receive another layer of coating. This may be repeated four to 12 times so that the wire receives a thick coating of many layers. After a final pass through the oven, the wire is wound on a spool for shipment to the customer.

1.2.2 Types of Emissions

The organic solvent content of wire coatings range from 67 to 85 percent by weight. Coating resins include the following compounds:

Polyester amide imide
Polyester
Polyurethane
Epoxy
Polyvinyl formal
Polyimide

In addition to solvent, from 10 to 25 percent of the coating resins may be volatilized in the drying ovens and emitted with oven exhaust.[1] Most of the volatilized resin condenses in the atmosphere to form a particulate, but some breaks down to form VOC.

Coating resins may be dissolved in a variety of solvents. Cresylic acid and various cresols are major solvents. Xylene and mixtures of C_8 - C_{12} aromatics are widely used also. The following solvents are used to some degree.

Cresylic acid	Hi-Flash naptha
Xylene	Methyl ethyl ketone
Alcohols	N-methyl pyrrolidine
Cresols, meta para	Ortho cresol
Diacetone alcohol	Phenol
Toluene	

Cresols have a strong disagreeable odor which is usually noticeable inside a wire coating plant. This odor has been one incentive for many operators to install combustion systems to avoid complaints.

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2.0 APPLICABLE SYSTEMS OF EMISSION REDUCTION

2.1 INCINERATION (COMBUSTION SYSTEMS)

Incineration is the most common technique used to control emissions from wire coating ovens. Since these ovens operate at high temperature (greater than 350°C) and have moderate to high solvent loads (10 to 25 percent LEL) they provide a favorable situation for incinerator. Because the oven exhaust is relatively hot, little additional fuel is needed to reach the solvent combustion temperature. Furthermore, the fuel value of the exhausted solvent may be high enough that little extra fuel is required to heat the oven. Combustion systems have been variously referred to as incinerators, afterburners and oxidizers. For further details on the theory of incineration, see Chapter 3 of "Control of Volatile Organic Emissions from Existing Stationary Sources - Volume I: Control Methods for Surface-Coating Operations."[1]

The four basic types of incinerators are:

Internal catalytic
External catalytic
Internal thermal
External thermal

Figure 3 shows a diagram of an internal catalytic incineration. (This drawing is simplified for illustrative purpose; most ovens have two drying zones.) The catalyst is built as an integral part of the oven. Hot solvent-laden air from the drying chamber is circulated past the catalyst; combustion of solvents takes place in the presence of the catalyst at 260°C

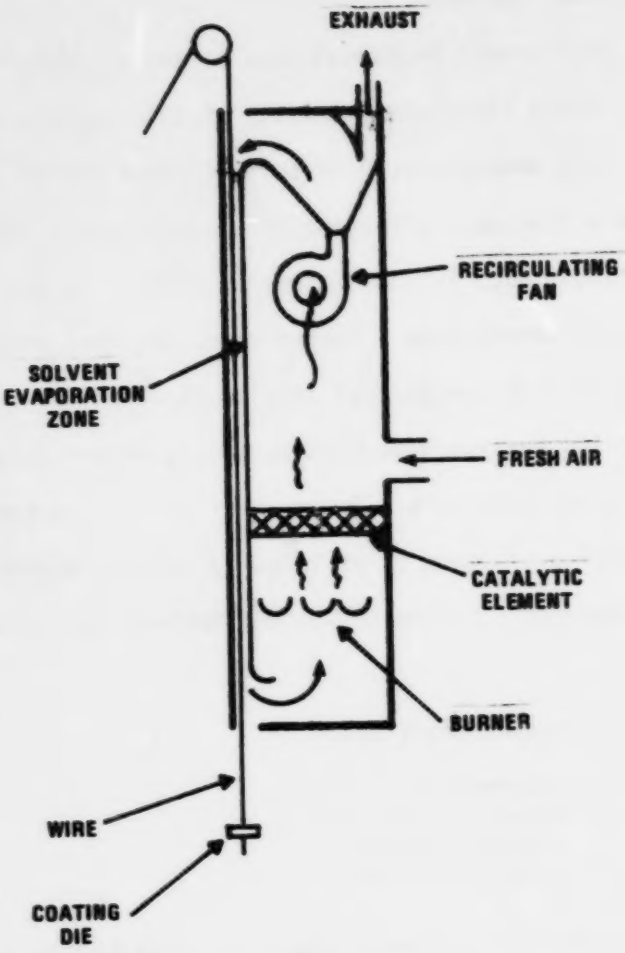

Figure 3. Wire coating oven with internal catalyst.

to 320°C. If the hot air from the drying chamber is in this temperature range, the oven operation may be self substaining. If not, a supplementary burner (electric or gas-fired) is used to raise the solvent-laden gases to the combustion temperature. The gases leave the catalyst at 450°C, and are recirculated back through the curing zone.

Internal catalytic incinerators were first introduced in the late 1950's. All major wire oven designers now incorporate metal catalysts into their new ovens. A representative of one major manufacturer stated that every wire oven built by his firm since 1960 has had an internal catalyst.[2]

There are three reasons why internal catalysts are so popular:

1. The internal catalyst burns solvent fumes and recirculates the heat back into the wire drying zone. Fuel otherwise needed to operate the oven is eliminated or greatly reduced.

2. Since the gases are cleaned and recirculated within the oven, less makeup air is required. This results in further energy savings.

3. Catalysts are reported to be to 95 percent efficient in destroying solvents.[3,4] However, others report that catalysts are only 75 to 90 percent efficiency, since efficiency drops off as the catalyst gets dirty.[5] Air pollution control has been of secondary importance to wire coaters; energy conservation is most important because of resultant cost savings.

An oven equipped with an external catalyst is shown in Figure 4. This type of modification is usually made to older wire coating ovens that do not have an internal catalyst.[6] The external catalyst system is added primarily for pollution control since the heat is not as easily recovered.

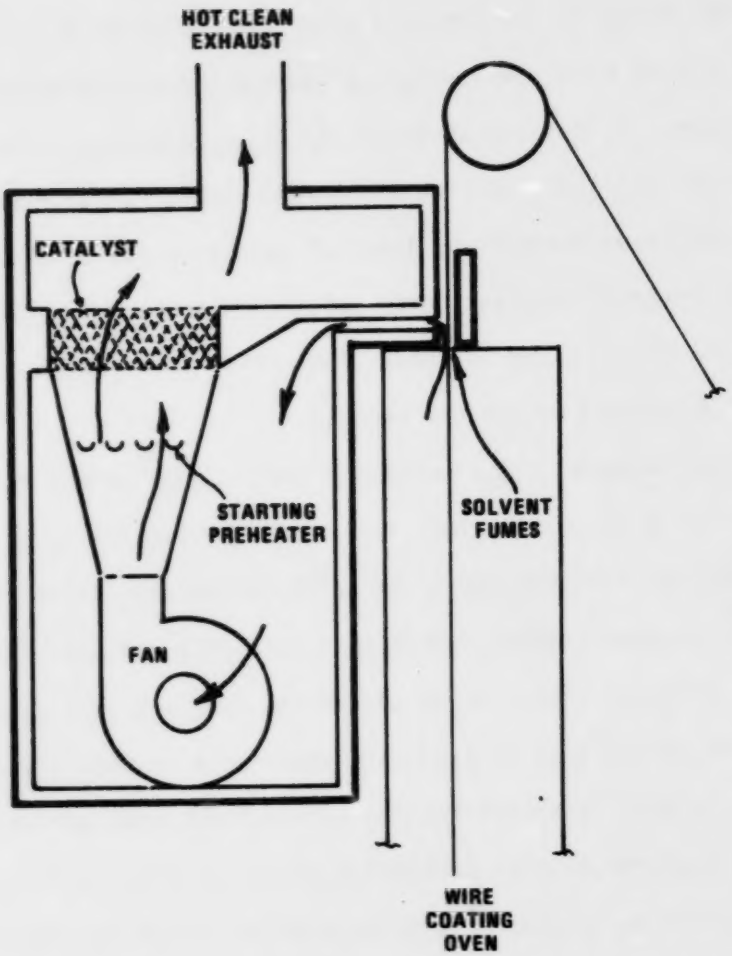

Figure 4. Wire coating oven with add-on catalytic incinerator.

A serious impediment to the future use of catalytic incinerators as air pollution devices for wire coating ovens is that some of the newer wire coatings, primarily polyester amide-imides, act as a catalyst poison.[7] Ordinarily, a wire coating catalyst can be used for 10,000 hours, but some coatings reduce the useful life to as little as 60 hours.[8] However, experimental catalysts are being developed which reportedly operate for 3,000 hours and possibly much longer using amide-imide coatings.[9]

Polyester amide-imide coatings have superior temperature resistance and allow electrical equipment to operate at higher temperatures, a very desirable quality. Wire coating plants which convert to these coatings will be unable to use catalytic incinerators and will likely use thermal incinerators for air pollution control.

A simplified drawing of an internal thermal incinerator (oxidizer) is shown in Figure 5. Solvent-laden gases from the drying zone are drawn past the thermal oxidizer where they are combusted with 98 percent efficiency.[10] The hot clean gases are then recirculated back to the drying zone. This type of incinerator has not been popular with wire coaters, reportedly because of high fuel usage.

External thermal incinerators are used mainly for air pollution control. Usually the discharge from 10 to 15 wire ovens are manifolded to each incinerator such that the total volume is 250 to 450 dscm per minute. Usually the inlet to the incinerator is preheated by contact with the incinerator exhaust gases (primary heat exchange). Secondary heat recovery systems are also employed on many large existing installations, principally for space heating.[11,12]

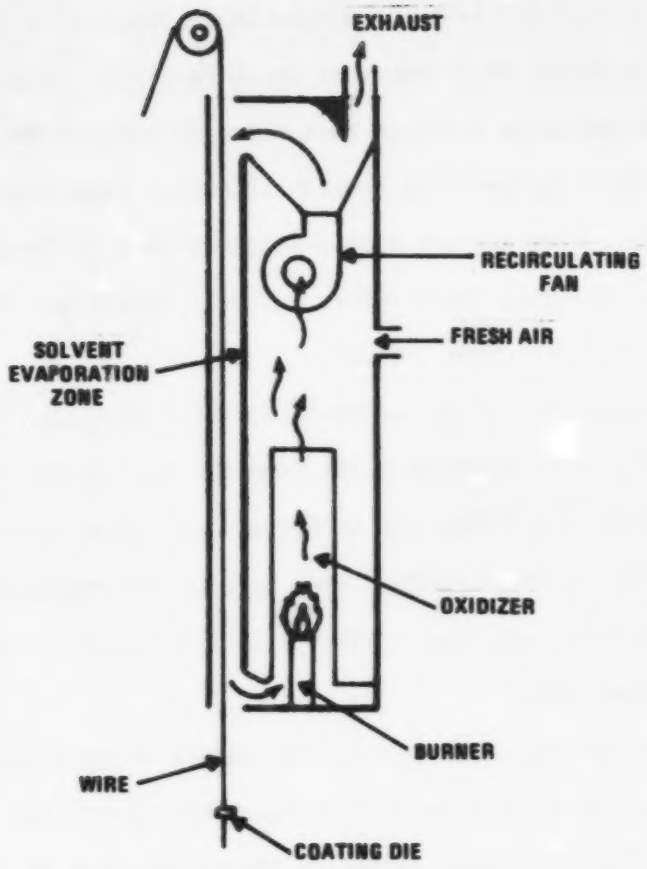

Figure 5. Wire coating oven with internal thermal oxidizer.

2.2 CARBON ADSORPTION

Carbon adsorption is not used as a control method in this industry for several reasons:

1. Wire ovens exhaust at 200°C to 380°C. The gases would have to be cooled to 38°C before adsorption would be effective.

2. Resins volatilized in the oven would tend to foul the carbon bed and create maintenance problems unless (or even if) prefilters were employed.

3. Since collected solvent mixtures would not be reused in the process, the recovery credit is relatively small.

2.3 LOW SOLVENT COATINGS

Low solvent coatings offer only a potential alternate way of reducing solvent emissions. Unfortunately, low solvent coatings have not yet been developed with the properties that will meet all wire coating needs.

Water-borne wire coatings, the most advanced low solvent technology, are being used in small quantities. One plant reportedly coats 10 percent of its production with water-borne coatings. These however, are not available with properties suitable for all wire coating applications. High temperature resistance is not as good with water-borne wire coatings.

Powder coatings have been applied to wire on an experimental basis. A powder coating line at the Westinghouse Wire Division plant (Abingdon, Virginia) was featured in Products Finishing magazine in February 1975.[13] Westinghouse has been experimenting with powder coatings since 1967. Powder coating applications have been limited for the following reasons:

1. Epoxy powders are the main type available; unfortunately, the upper temperature range for an epoxy coating is only 130°C whereas many types of electrical equipment must operate at temperatures up to 220°C.[14]

2. Powder can be used only on larger diameter wires. For finer wire, the powder particle approaches the wire diameter and will not adhere well to the wire.

Several other types of low solvent wire coatings are in the experimental stage. Hot melt coatings, which are applied as a molten mass and have no solvents, have reportedly been used successfully in Europe.[15] Ultraviolet cured coatings are now available for specialized systems. Electrodeposition coatings are theoretically possible, but once a layer of coating is applied to the wire, the surface is insulated against further electrodeposition. Thus, thick films cannot be built up.

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3.0 COST ANALYSIS

3.1 INTRODUCTION

3.1.1 Purpose

The purpose of this chapter is to present estimated costs for control of volatile organic compound (VOC) emissions from wire coating lines at existing magnet wire coating plants.

3.1.2 Scope

Estimates of capital and annualized costs are presented for controlling solvent emissions from drying ovens of existing magnet wire coating lines using external (add-on) catalytic and thermal incinerators. Control costs are developed for four model sizes - one, five, 10 and 15 ovens per incinerator. Each oven is medium size with emission exhausts averaging 28 dscm per minute and production averaging 690 Mg per year of wire coated. Incinerators are costed with and without solvent heat recovery. Cost effectiveness ratios (annualized costs per megagram of solvent emissions controlled) are shown for the single and multiple model oven configurations.

Most wire coating ovens built since the early 1960's have built-in (internal) incinerators.[1,2] Since this report is concerned with existing facilities, control costs of internal catalytic and thermal incinerators are not included. Other techniques, such as carbon adsorption, are not costed since they are not used as control methods in the wire coating industry (see sections 2.2 and 2.3).

3.1.3 Use of Model Emission Points

Wire coating plants vary considerably as to the number and type of ovens; the size, type and speed of wire processed; the types of coatings applied; and the number of ovens per incinerator.[2,3,4,5,6] Since an actual plant is likely to have significantly different control costs than another actual plant and the wide variety of installations reduces the applicability of a model plant, the use of model emission points becomes a necessity. Therefore, the cost analyses in this chapter are based on model emission points - single and multiple drying oven models. The technical parameters used for the model ovens have been selected to represent typical operating conditions at actual wire coating plants and are listed in Table 3-1. Although model oven control costs may differ with actual costs incurred, they are the most convenient means of comparing the relative costs of control options.

3.1.4 Bases for Capital and Annualized Cost Estimates

Capital cost estimates represent the total investment required to purchase and install a particular control system. Cost estimates were obtained from EPA contractor reports, equipment vendors and plant installations. Retrofit installations are assumed. Costs for research and development, production losses during installation and start-up, and other highly variable costs are not included in the estimates. All capital costs reflect second quarter 1977 dollars.

Annualized control cost estimates include operating labor, maintenance, utilities, and annualized capital charges. Reduced fuel (utility) costs are based on 35-50% primary heat recovery for the incinerators with heat exchangers.

Table 3-1. TECHNICAL PARAMETERS USED IN DEVELOPING CONTROL COSTS[a]

I.	VOC Emission Rate:	12 Kg/hr.
II.	VOC Concentration:	15% LEL
III.	Average Exhaust Flowrate	28 dscm/min. (990 dscfm)
IV.	Exhaust Temperatures:	
	Catalytic Incineration:	260° C to 450°C (500°F to 842°F)
	Thermal Incineration:	760°C (1400°F)
V.	Incineration Residence Time:	0.5 sec.[b]
VI.	VOC Control Efficiencies:	
	Catalytic Incineration:	90%
	Thermal Incineration:	90%
VII.	Heat Recovery Efficiencies:[c]	
	Catalytic:	35-45% (Primary)
	Thermal:	35-50% (Primary)
VIII.	Operating Factor:[d]	7000 hours/year
IX.	Average Densities:	
	Solvent:	0.882 Kg/liter (7.36 lb/gal.)
	Coatings:	1.138 Kg/liter (9.5 lb/gal.)
X.	Ratio of Uncontrolled Solvent Emissions to Wire Production:[e]	

$$\frac{\text{Average Uncontrolled Solvent Emissions}}{\text{Average Wire Production}} = \frac{10.9 \text{ Kg}}{100 \text{ Kg}}$$

[a] Except as noted, values are taken from Chapter 2.

[b] EPA estimate.

[c] References 7 and 10.

[d] Reference 8.

[e] Reference 9.

The annualized capital charges are sub-divided into capital recovery costs (depreciation and interest costs) and costs for property taxes, insurance and administration. Depreciation and interest costs have been computed using a capital recovery factor based on a 10 year depreciation life of the control equipment and an interest rate of 10% per annum. Costs for property taxes, insurance and administration are computed at 4% of the capital costs. All annualized costs are for one year periods commencing with the second quarter of 1977.

3.2 CONTROL OF SOLVENT EMISSIONS FROM WIRE COATING OPERATIONS

3.2.1 Model Cost Parameters

Control costs have been developed for four model sizes using each of the following incineration devices: catalytic incinerator without heat exchanger; catalytic incinerator with heat exchanger; thermal incinerator without heat exchanger; and thermal incinerator with heat exchanger. All incinerators are external (add-on) units. Table 3-2 presents the cost parameters for each of the four model sizes. These parameters are based upon studies of the wire coating industry by contractors and the EPA.

3.2.2 Control Costs

Table 3-3 presents control costs for the single oven model (one oven per incinerator) using four different external control devices: catalytic incinerator with and without heat exchanger, and thermal incinerator with and without heat exchanger. Similarly, Tables 3-4, 3-5, and 3-6 present control costs of the four control devices for the 5-oven, 10-oven and 15-oven models. Very high installation costs (75-90% of equipment costs) have been allowed for all multiple oven models to provide for additional costs of

Table 3-2. COST PARAMETERS USED IN COMPUTING ANNUALIZED COSTS

Model	Number of Ovens per Incinerator	Emission Flowrates[a] Before Control		Average Wire[b] Production	
		$dsm^3/min.$	(dscfm)	Mg/Yr.	(1000 lb/yr.)
I	1	28	(990)	690	(1520)
II	5	140	(4950)	3,450	(7600)
III	10	280	(9900)	6,900	(15,200)
IV	15	420	(14850)	10,350	(22,800)

[a]Chapter 2.

[b]Average wire production from References 8, 9, and 11; actual wire production will vary and depends on the size and speed of the wire, the number of wires per oven and the number of passes through the oven.

Table 3-3. CONTROL COSTS FOR MODEL I (one oven per incinerator; 28 dsm^3/min. emission flowrate before control)

	External Catalytic Incinerator[g]		External Thermal Incinerator	
	With Heat Exchanger	Without H. E.	With Heat Exchanger	Without H.E.
Installed Capital Cost ($000)[a]	60.0	39.6	50.0	30.0
Direct Operating Cost ($000/yr)[b]	5.4	12.2	10.3	24.5
Annualized Capital Charges ($000/yr)[c]	12.2	8.0	10.1	6.1
Total Annualized Cost ($000/yr)[d]	17.6	20.2	20.4	30.6
Solvent Emissions Controlled (Mg/yr)[e]	75.6	75.6	75.6	75.6
Cost per Mg Emissions Controlled ($/Mg)[f]	235	265	270	405

Table 3-4. CONTROL COSTS FOR MODEL II (Five ovens per incinerator; 140 dsm^3/min. emission flowrate before control)

	External Catalytic Incinerator[g]		External Thermal Incinerator	
	With Heat Exchanger	Without H.E.	With Heat Exchanger	Without H.E.
Installed Capital Cost ($000)[h]	140.0	105.0	135.0	100.0
Direct Operating Cost ($000/yr)[b]	22.5	45.0	40.0	80.0
Annualized Capital Charges ($000/yr)[c]	28.4	21.3	27.4	20.3
Total Annualized Cost ($000/yr)[d]	50.9	66.3	67.4	100.3
Solvent Emissions Controlled (Mg/yr)[e]	378.0	378.0	378.0	378.0
Cost per Mg Emissions Controlled ($/Mg)[f]	135	175	180	265

[a]References 2, 7, 8, 11, 12 and 13; high installation costs (65% to 70% of purchased equipment costs) have been allowed.

[b]Average annual operating and maintenance costs per References 7 and 10, assuming the use of natural gas and electric energy. The multiple oven model costs have been compared with References 14 and 15.

[c]Capital recovery costs (using capital recovery factor with 10% interest rate and 10 year equipment life) plus 4% of capital costs for property taxes, insurance and administration.

[d]Sum of Direct Operating Cost and Annualized Capital Charges.

[e]Product of Uncontrolled VOC Emission Rate times Operating Factor Times Control Efficiency.

[f]Total Annualized Cost divided by the Solvent Emissions Controlled.

[g]Catalysts assumed to have normal replacement lives and will not become prematurely poisoned by metallic coatings.

[h]Average installed capital costs per References 10, 14, 15, and 16; very high installation costs (75% to 90% of purchased equipment costs) have been allowed to provide for additional costs of ducting, controls, lines, auxiliary equipment and some supporting structures.

Table 3-5. CONTROL COSTS FOR MODEL III (10 ovens per incinerator; 280 dsm^3/min. emission flowrate before control)

	External Catalytic Incinerator [g]		External Thermal Incinerator	
	With Heat Exchanger	Without H. E.	With Heat Exchanger	Without H.E.
Installed Capital Cost ($000) [h]	225.0	175.0	220.0	178.0
Direct Operating Cost ($000/yr) [b]	40.0	81.0	70.0	145.0
Annualized Capital Charges ($000/yr) [c]	45.6	35.5	44.6	36.1
Total Annualized Cost ($000/yr) [d]	85.6	116.5	114.6	181.1
Solvent Emissions Controlled (Mg/yr) [e]	756.0	756.0	756.0	756.0
Cost per Mg Emissions Controlled ($/Mg) [f]	115	115	150	240

Table 3-6. CONTROL COSTS FOR MODEL IV (15 ovens per incinerator; 420 dsm^3/min emission flowrate before control)

	External Catalytic Incinerator [g]		External Thermal Incinerator	
	With Heat Exchanger	Without H.E.	With Heat Exchanger	Without H.E.
Installed Capital Cost ($000) [h]	315.0	250.0	325.0	270.0
Direct Operating Cost ($000/yr) [b]	55.0	117.0	98.0	210.0
Annualized Capital Charges ($000/yr) [c]	63.9	50.7	65.9	54.7
Total Annualized Cost ($000/yr) [d]	118.9	166.7	163.9	264.7
Solvent Emissions Controlled (Mg/yr) [e]	1,134.0	1,134.0	1,134.0	1,134.0
Cost per Mg Emissions Controlled ($/Mg) [f]	105	145	145	235

[b] Average annual operating and maintenance costs per References 7 and 10, assuming the use of natural gas and electric energy. The multiple oven model costs have been compared with References 14 and 15.

[c] Capital recovery costs (using capital recovery factor with 10% interest rate and 10 year equipment life) plus 4% of capital costs for property taxes, insurance and administration.

[d] Sum of Direct Operating Cost and Annualized Capital Charges.

[e] Product of Uncontrolled VOC Emission Rate times Operating Factor Times Control Efficiency.

[f] Total Annualized Cost divided by the Solvent Emissions Controlled.

[g] Catalysts assumed to have normal replacement lives and will not become prematurely poisoned by metallic coatings.

[h] Average installed capital costs per References 10, 14, 15, and 16; very high installation costs (75% to 90% of purchased equipment costs) have been allowed to provide for additional costs of ducting, controls, lines, auxiliary equipment and some supporting structures.

ducting, controls, lines, auxiliary equipment and some supporting structures; while high installation costs (65% to 70% of equipment costs) have been allowed for the single oven model. Wherever possible, the cost estimates have been compared with industry costs.[2,8,11,12,13,14,15,16] But, it is recognized that control costs of actual installations may vary from the estimates.

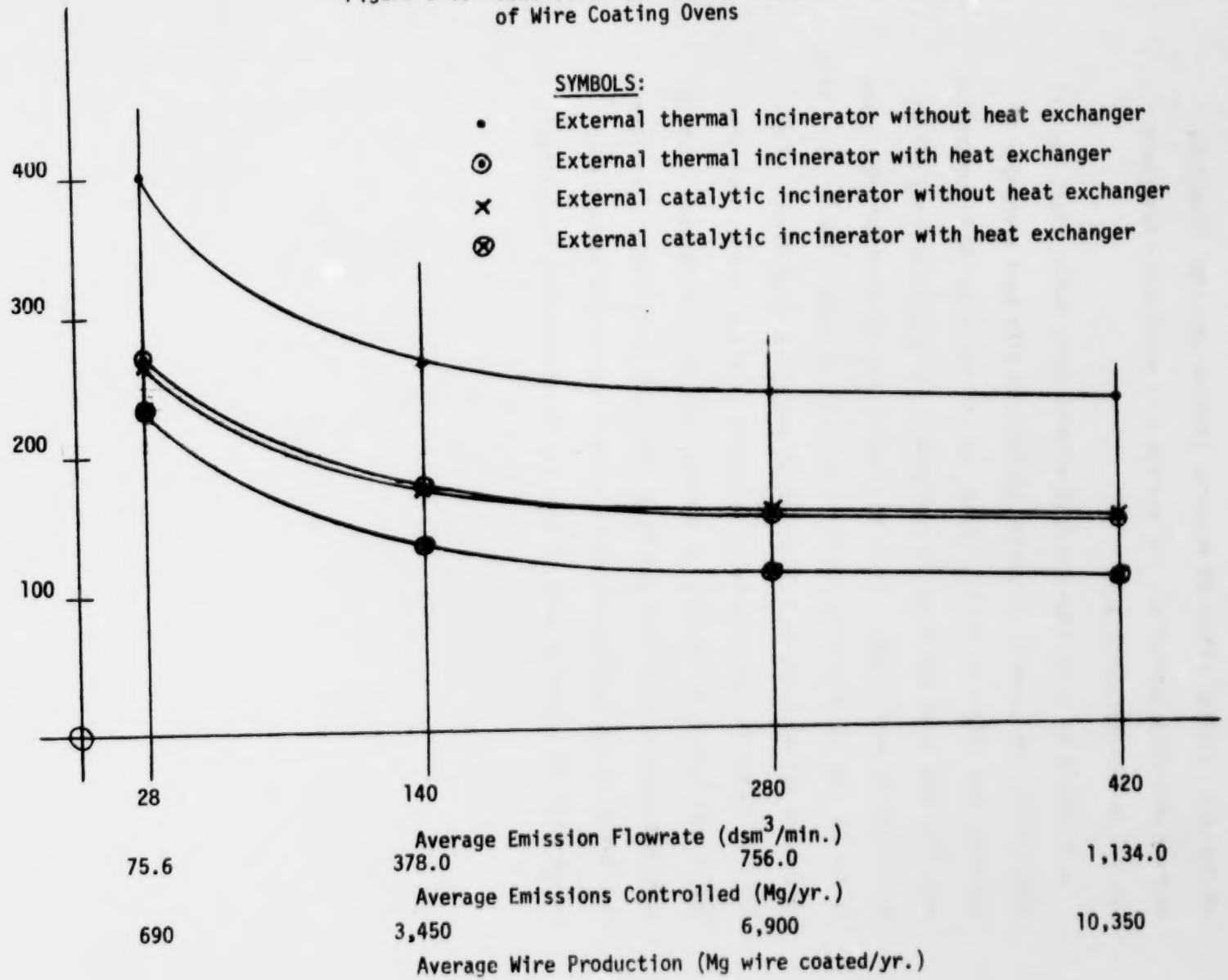
The solvent emissions controlled per year are determined as the uncontrolled VOC emission rate times the operating factor times the control efficiency. For example, the single oven model solvent emissions controlled are calculated as (12 Kg/hr) (7000 hrs/yr) (.90) = 75,600 Kg/Yr. The cost per Mg of controlled emissions is the total annualized cost divided by the solvent emissions controlled, or $17,600/75.6 Mg = $235 per Mg for the single oven model using catalytic incineration with heat recovery.

As evidenced by the estimates, the catalytic incinerators, both with and without heat exchangers, have lower operating costs than the corresponding thermal devices. The catalysts cause combustion to occur at lower temperatures, thus requiring less fuel than the thermal devices. These costs assume that the catalysts will have normal replacement lives and will not become prematurely poisoned by metallic coatings (see Section 2.1). Also, for each model size, the incinerators with heat exchangers have higher capital costs and lower operating costs than those without heat exchangers. This relationship is due to the additional capital cost of the heat exchangers (and auxiliary equipment) and the resulting fuel savings obtained from 35 to 50% primary heat recovery.

3.2.3 Cost Effectiveness

Figure 3-1 graphically depicts the estimated cost-effectiveness of the four external control devices for the four model sizes. For the convenience

Figure 3-1. Cost-effectiveness of VOC Emission Control of Wire Coating Ovens



of the user, several different measures (average emission flowrates, average emissions controlled, and average wire production) have been plotted on the horizontal axis.

It should be noted from the cost-effectiveness curves that, for all model sizes, the external catalytic incinerator with heat exchanger is the most cost effective device. Also, control costs per Mg of controlled emissions are lower for multiple oven models and appear to level off at the 10 and 15 oven models. Thus, the lowest cost emission control system is the 15-oven catalytic incinerator with heat exchanger; the costs of this system are estimated to be $105 per Mg of emissions controlled. If a catalyst cannot be used because of poisoning or other reason, then the lowest cost system is the 15-oven thermal incinerator with heat recovery, at an estimated cost of $145 per Mg of emissions controlled. The highest cost device is the single-oven model thermal incinerator without heat exchanger at an estimated cost of $405 per Mg of emissions controlled.

3.3 REFERENCES

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4.0 ADVERSE AND BENEFICIAL EFFECTS OF APPLYING TECHNOLOGY

4.1 BENEFICIAL EFFECTS

About 29,500 metric tons of solvents are used in the insulation varnishes, including wire coatings, each year.[1] Much of this is now burned within drying ovens since most wire coating ovens installed since 1960 have internal catalytic incinerators. This type of oven has grown in popularity because it utilizes the heat of combustion of the exhaust gases, eliminates malodors and avoids buildup of flammable resins in the stack. However, the catalysts in many of these catalytic incinerators may have been poisoned or have lost reactivity. Also, some older ovens have no controls at all, so there is no way to know how much solvent is actually emitted. Unquestionably, however, uniform application of control restrictions would effect a reduction in emissions.

4.2 ADVERSE EFFECTS

Wire coating ovens are generally built with a catalyst within the oven thereby taking advantage of the heat of combustion of the coating solvent to reduce fuel requirements. Where an external afterburner must be retrofitted, however, the oven system may not be designed to benefit by the heat made available. Consequently, the fuel requirements for operating the line would increase.

4.3 REFERENCES

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5.0 MONITORING TECHNIQUES AND ENFORCEMENT ASPECTS

The suggested emission limitations will probably be met with an incinerator. Wire ovens are enclosed and hooding should be designed to capture and direct essentially all solvent to the incinerator. The main problem of the control official is determining that the incinerator is operating correctly. A measurement of combustion efficiency across the incinerator could be required when the unit is installed. (One test may be adequate when several identical units are installed.)

A thermal incinerator which shows a high combustion efficiency will probably continue to perform well if operated under the same temperature conditions. Normally, a temperature indicator reading in the combustion chamber is sufficient to monitor proper operation. For catalytic incinerators, the temperature rise across the catalyst bed should be measured during the test for combustion efficiency. This temperature rise reflects the activity of the catalyst.

Wire oven catalysts normally have a finite life of 6,000 to 14,000 hours. The plant should be required to replace catalysts after 10,000 hours of operation unless the plant can document that the catalysts will operate longer. Catalysts which are exposed to polyester amide imide coatings may become deactivated in as little as 60 hours. Thermal incinerators should be required to control coatings which poison catalysts. Catalyst performance can be monitored by temperature indicator.

There are several techniques for testing the efficiency across an incinerator. For a more detailed discussion of organic compound test methods, see Chapter 5, "Approaches to Determination of Total Nonmethane Hydrocarbons", in Volume I of this series.[1]

5.1 REFERENCES

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